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Influence of Time of Planting on the Growth of Sugarcane Variety P.R. 980 at Río Piedras

S. Alers-Alers, G. Samuels, and P. Landrau, Jr.[1]

INTRODUCTION

In the Temperate Zone, almost everyone is familiar with the influence of the season on plant growth. In the spring, plant growth begins anew after the cold winter; the summer with its high temperatures and bright sun brings rapid growth; and in the autumn plant growth slows down and maturity of many plants occurs just before the rigors of the winter weather set in. Despite the absence of snow or freezing temperatures, subtropical climates such as that of Puerto Rico, also experience seasonal changes in growth rate. From visual observations the sugarcane grower in Puerto Rico is aware of the very slow growth of sugarcane in the winter months of December, January, and February, and of its rapid growth during the summer months of June, July, and August.

Stender (*3*)[2] has shown that, in Hawaii, cane growth, as measured by both cane elongation and increased volume, was highly related to air temperature, increased growth being associated with increases in the mean daily temperature. Clements and Kubota (*2*) found a positive correlation between the moisture content of the elongating cane and meristem, and the rate of elongation. A high positive correlation between rate of stalk elongation and rainfall has been reported from Formosa by Sun and Chow (*4*).

For Puerto Rico there appears to be no published information available on growth measurements for sugarcane except for the work of Brandes (*1*) who compared the growth of many of the *Saccharum* species at six selected stations at different latitudes, including Puerto Rico. Aside from random field observations, no specific study has been made in Puerto Rico on rates of growth for sugarcane for various planting dates. It is the purpose of

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[2] Italic numbers in parentheses refer to Literature Cited, p. 52.

this paper to report data on the influence that the time of the year sugarcane variety P.R. 980 is planted exerts on its growth.

PROCEDURE

The data for this study were taken from a time-of-planting and harvesting experiment established at Río Piedras by the Agronomy and Horticulture Department of the Agricultural Experiment Station, University of Puerto Rico. Sugarcane variety P.R. 980 was planted at 28-day intervals for 14 plantings, beginning on May 31, 1955. Each planting consisted of 28 rows of cane 4½ feet apart and 24 feet long, giving a plot size of 0.70 acre. The plantings were replicated four times in a randomized block design.

Measurements of growth were made every 28 days beginning 1 month after planting. Eight measurements were made for each planting until the cane had reached an age of 7 months. Measurements were then discontinued because of the difficulty in movement within the experiment to make them. The measurements of the cane were made 1 inch from the soil surface to the top of the upmost visible ligule of the cane sheath. To minimize error due to changes in the height of the soil surface by erosion or cultivation, a wooden reference stake was driven into the soil at the base of the plant with the top of the stake 1 inch from the soil surface. This stake served as a reference point for all measurements. Twelve canes were measured in each plot. All measurements were made to the nearest ⅛ inch. For the sake of brevity all measurements given in this paper are averaged for all replications.

RESULTS

The accumulated growth measurements and rate of growth for P.R. 980 at various planting dates are given in tables 1 and 2, respectively.

The best growth of cane as measured by height was made with sugarcane planted in May and June (table 1) and the poorest growth was attained by the October and November plantings. The planting made on May 31, 1955 reached 91.56 inches in 7 months as compared with only 42.73 inches for the November planting.

The highest average growth rate for the entire 7-month period occurred in May and June plantings with the poorest rates in the October and November plantings (table 2). The average growth rate for the entire growth period measured was 11.1 inches per month for cane planted on May 31, 1955, and 5.0 inches per month for the November 15, 1955 planting.

A comparison of the heights of cane reached at 4 and 7 months is given in table 3. At an age of 4 months, sugarcane in Puerto Rico is normally considered to have grown sufficiently to close-in a field. The closing-in of a field is considered beneficial in that the dense growth of cane prevents or

TABLE 1.—*The height, in inches, of sugarcane planted at various dates throughout the year and measured for a period of 7 months at 28-day intervals, plant crop of P.R. 980 at Solis Farm, Rio Piedras*

Date of measurement	Measurement of the height of the cane, in inches, for the planting dates indicated													
	May 31, 1955, I	June 28, 1955, II	July 26, 1955, III	Aug. 23, 1955, IV	Sept. 20, 1955, V	Oct. 18, 1955, VI	Nov. 15, 1955, VII	Dec. 13, 1955, VIII	Jan. 10, 1956, IX	Feb. 7, 1956, X	Mar. 6, 1956, XI	Apr. 3, 1956, XII	May 1, 1956, XIII	May 29, 1956, XIV
June 30, 1955	2.96	—	—	—	—	—	—	—	—	—	—	—	—	—
July 28, 1955	7.20	3.64	—	—	—	—	—	—	—	—	—	—	—	—
Aug. 25, 1955	15.56	7.02	3.09	—	—	—	—	—	—	—	—	—	—	—
Sept. 22, 1955	38.04	19.97	7.97	3.76	—	—	—	—	—	—	—	—	—	—
Oct. 20, 1955	58.47	43.11	18.62	8.80	3.87	—	—	—	—	—	—	—	—	—
Nov. 17, 1955	74.48	61.33	33.83	18.98	8.95	2.87	—	—	—	—	—	—	—	—
Dec. 15, 1955	83.58	71.01	45.52	32.54	11.49	5.06	2.77	—	—	—	—	—	—	—
Jan. 12, 1956	91.56	80.89	56.39	45.82	19.93	7.45	4.13	2.97	—	—	—	—	—	—
Feb. 9, 1956	—	86.15	61.07	53.21	26.71	10.34	5.91	4.66	4.64	—	—	—	—	—
Mar. 8, 1956	—	—	68.96	60.60	32.81	14.05	7.40	6.09	7.75	2.52	—	—	—	—
Apr. 5, 1959	—	—	—	71.10	42.37	22.59	11.97	10.94	14.39	4.71	3.58	—	—	—
May 3, 1956	—	—	—	—	57.78	36.30	24.25	25.16	23.63	11.50	7.83	4.67	—	—
May 31, 1956	—	—	—	—	—	44.93	32.11	39.31	37.07	23.65	17.58	8.11	4.29	—
June 28, 1956	—	—	—	—	—	—	42.73	51.29	50.00	36.96	32.05	16.40	7.38	4.36
July 26, 1956	—	—	—	—	—	—	—	69.70	60.99	57.52	54.04	34.90	24.11	12.06
Aug. 23, 1956	—	—	—	—	—	—	—	—	75.86	63.42	58.85	41.65	33.17	19.27
Sept. 20, 1956	—	—	—	—	—	—	—	—	—	75.76	71.27	57.13	48.44	37.22
Oct. 18, 1956	—	—	—	—	—	—	—	—	—	—	83.38	72.85	64.76	55.09
Nov. 15, 1956	—	—	—	—	—	—	—	—	—	—	—	81.62	76.37	66.31
Dec. 13, 1956	—	—	—	—	—	—	—	—	—	—	—	—	85.68	77.10
Jan. 10, 1957	—	—	—	—	—	—	—	—	—	—	—	—	—	85.46

TABLE 2.—*Average rate of growth per month, in inches, of sugarcane planted at various dates throughout the year, plant crop of P.R. 980 at Solís Farm, Río Piedras*

Period of growth	Average rate of growth, in inches, for the planting dates indicated													
	May 31, 1955, I	June 28, 1955, II	July 26, 1955, III	Aug. 23, 1955, IV	Sept. 20, 1955, V	Oct. 18 1955, VI	Nov. 15, 1955, VII	Dec. 13, 1955, VIII	Jan. 10, 1956, IX	Feb. 7, 1956, X	Mar. 6, 1956, XI	Apr. 3, 1956, XII	May 1, 1956, XIII	May 29, 1956, XIV
June 30–July 28	4.24	—	—	—	—	—	—	—	—	—	—	—	—	—
July 28–Aug. 25	8.36	3.38	—	—	—	—	—	—	—	—	—	—	—	—
Aug. 25–Sept. 22	22.48	12.95	4.88	—	—	—	—	—	—	—	—	—	—	—
Sept. 22–Oct. 20	20.43	23.14	10.65	5.04	—	—	—	—	—	—	—	—	—	—
Oct. 20–Nov. 17	16.01	18.22	15.21	10.18	5.08	—	—	—	—	—	—	—	—	—
Nov. 17–Dec. 15	9.10	9.68	11.69	13.56	2.54	2.19	—	—	—	—	—	—	—	—
Dec. 15–Jan. 12	7.98	9.88	10.87	13.28	8.44	2.39	1.36	—	—	—	—	—	—	—
Jan. 12–Feb. 9	—	5.26	4.68	7.39	6.78	2.89	1.78	1.69	—	—	—	—	—	—
Feb. 9–Mar. 8	—	—	7.89	7.39	6.10	3.71	1.49	1.43	3.11	—	—	—	—	—
Mar. 8–Apr. 5	—	—	—	10.50	9.56	8.54	4.57	4.85	6.64	2.19	—	—	—	—
Apr. 5–May 3	—	—	—	—	15.41	13.71	12.28	14.22	9.24	6.79	4.25	—	—	—
May 3–May 31	—	—	—	—	—	8.63	7.86	14.15	13.44	12.15	9.75	3.44	—	—
May 31–June 28	—	—	—	—	—	—	10.62	11.98	12.93	13.31	14.47	8.29	3.09	—
June 28–July 26	—	—	—	—	—	—	—	18.41	10.99	20.56	21.99	18.50	16.73	7.70
July 26–Aug. 23	—	—	—	—	—	—	—	—	14.87	5.90	4.81	6.75	9.06	7.21
Aug. 23–Sept. 20	—	—	—	—	—	—	—	—	—	12.34	12.42	15.48	15.27	17.95
Sept. 20–Oct. 18	—	—	—	—	—	—	—	—	—	—	12.11	15.72	16.32	17.87
Oct. 18–Nov. 15	—	—	—	—	—	—	—	—	—	—	—	8.77	11.61	11.22
Nov. 15–Dec. 13	—	—	—	—	—	—	—	—	—	—	—	—	9.31	10.79
Dec. 13–Jan. 10	—	—	—	—	—	—	—	—	—	—	—	—	—	8.36

TABLE 3.—*Height of sugarcane and yields of cane per acre as influenced by the time of planting, plant crop of P.R. 980 at Solís farm, Río Piedras*

Planting No.	Date of planting	Height of cane at—		Average rate of growth per month	Yield of cane per acre when harvested at—		Dates covered by the 8-month period of growth in which measurements were taken
		4 months	7 months		12 months	18 months	
		Inches	*Inches*	*Inches*	*Tons*	*Tons*	
1	May 31, 1955	38	92	11.1	81	132	June 20, 1955 to Jan. 12, 1956
2	June 28, 1955	43	86	10.7	99	136	July 28, 1955 to Feb. 9, 1956
3	July 26, 1955	34	69	8.2	88	127	Aug. 25, 1955 to Mar. 8, 1956
4	Aug. 23, 1955	33	71	8.4	92	107	Sept. 22, 1955 to Apr. 5, 1956
5	Sept. 20, 1955	20	58	6.7	75	95	Oct. 20, 1955 to May 3, 1956
6	Oct. 18, 1955	10	45	5.3	70	86	Nov. 17, 1955 to May 31, 1956
7	Nov. 15, 1955	7	43	5.0	59	73	Dec. 15, 1955 to June 28, 1956
8	Dec. 13, 1955	11	70	8.8	84	92	Jan. 12, 1956 to July 26, 1956
9	Jan. 10, 1956	24	76	8.9	67	80	Feb. 9, 1956 to Aug. 23, 1956
10	Feb. 7, 1956	24	76	9.2	64	79	Mar. 8, 1956 to Sept. 20, 1956
11	Mar. 6, 1956	32	83	10.0	71	105	Apr. 5, 1956 to Oct. 18, 1956
12	Apr. 3, 1956	35	82	9.6	73	109	May 3, 1956 to Nov. 15, 1956
13	May 1, 1956	33	86	10.2	64	102	May 31, 1956 to Dec. 13, 1956
14	May 29, 1956	37	86	10.1	72	94	June 28, 1956 to Jan. 10, 1957

limits weed growth, thus reducing weeding costs. Table 3 shows that canes planted from September to February were 2 feet or less in height at 4 months, and not tall enough to prevent weed growth. Cane planted from April to August reached heights of 3 feet or more at 4 months and required less weeding.

Sugarcane at 7 months attained heights of about 7 feet and over when planted from March to June, and heights of only about 4 feet for October and November plantings. In fact, cane planted on June 28, 1955, had the same height, 43 inches at 4 months of age, as cane planted on November 15, 1955, at 7 months of age.

Good cane growth normally means good cane tonnage. The yields of cane per acre for the various planting dates are given in table 3 as 12-month and 18-month cane. The lowest cane yields per acre were associated with the lowest average rate of growth per month and also cane height at 4 and 7 months. Highest cane tonnages were not necessarily associated with highest average growth rates nor heights of cane at 4 or 7 months.

The poor growth of sugarcane obtained in the winter reflects lower temperatures, fewer hours of sunlight, and lower rainfall occurring in Puerto Rico during the winter months.

In table 4, the average rainfall, hours of sunlight, and temperatures per month for Río Piedras are shown together with the height of cane per month. Sugarcane planted in November must make its initial months of growth in a time of poor rainfall and low temperatures. Cane planted on May 30 has the summer with its abundant rainfall and high temperatures to grow in. The May-planted cane enters the winter period at 7 months of age and almost 5 feet in height, with an abundant leaf surface to make a better use of the lower photoperiod in the winter. This more developed cane also has a larger root system which can penetrate deeper into the soil to obtain moisture. November-planted cane has but a few thin leaves to use for its photosynthetic activity and a small shallow root system which suffers from lack of rain in the winter.

SUMMARY

Sugarcane variety P.R. 980 was planted at 28-day intervals throughout the year in Río Piedras, P. R. Measurements of growth were made on these plantings each month. The influence of the time of planting on growth was found to be as follows:

1. The best growth, as measured by heights of cane at 7 months, was made by sugarcane planted in May and June and the poorest growth by October and November plantings.

2. The highest average rate of growth for the 7-month period was made

by cane planted in May and June and the lowest for October and November plantings.

3. A comparison of the heights of cane reached at 4 months revealed that cane planted from April to August attained 3 feet or more and required

TABLE 4.—*Monthly rainfall, mean temperature, total hours of sunlight, and accumulated height of cane P.R. 980, planted May 30 and November 15*

Month	Rainfall	Mean daily temperature	Possible sunshine as total per day	Height of cane
		May 30 planting		
	Inches	*°F*	*Minutes*	*Inches*
June	6.4	78.1	396	3.0
July	8.0	79.4	406	7.2
August	8.4	80.2	394	15.6
September	8.0	79.8	367	38.0
October	6.6	79.4	364	58.5
November	7.2	77.7	339	74.5
December	6.2	75.3	343	83.6
Average	7.3	78.6	373	83.6
		November 15 planting		
November	7.2	77.7	339	2.8
December	6.2	75.3	343	4.1
January	4.9	73.0	346	5.9
February	3.5	72.9	324	7.4
March	3.3	74.4	374	12.0
April	4.5	76.1	377	24.3
May	7.4	77.7	402	32.1
Average	5.3	75.3	358	32.1

less weeding than cane planted from September to February, which measured 2 feet and under.

4. The lowest cane tonnage at 12 and 18 months was associated with the lowest average rate of growth per month, but the highest cane tonnages were not necessarily associated with highest average growth rates nor heights of cane at 4 or 7 months.

RESUMEN

En Río Piedras, distintas parcelas de la variedad de caña de azúcar P. R. 980 se sembraron a intervalos de 28 días durante doce meses. Se midió su

crecimiento cada mes. Los efectos del tiempo en que cada parcela fué sembrada sobre los índices de crecimiento de la caña fueron como sigue:

1. El mayor crecimiento de la caña, medido 7 meses después de sembrada, se registró en las parcelas sembradas en mayo y junio. El menor crecimiento, igualmente medido en cañas de 7 meses, se registró en las parcelas sembradas en octubre y noviembre.

2. El promedio de crecimiento mayor en cañas de 7 meses fué el correspondiente a las cañas sembradas en mayo y junio, mientras que el más bajo correspondió a las sembradas en octubre y noviembre.

3. Cuando se comparó la altura de las cañas a los 4 meses de sembradas se comprobó que las sembradas de abril a agosto alcanzaron alturas de 3 pies o más, y las que se sembraron de septiembre a febrero sólo alcanzaron 2 pies o menos de altura. Es obvio que las primeras no necesitaron tantos desyerbos como las segundas.

4. El tonelaje mayor de caña, según este estudio, no fué necesario asociarlo a los indices más altos de crecimiento ni a los promedios de altura alcanzados en cañas de 4 a 7 meses, sin embargo, el tonelaje menor obtenido de cañas de 12 a 18 meses de sembradas hubo que asociarlo a su índice de crecimiento, el cual fué el más bajo por mes.

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Taxonomic Description and Reproductive Behavior of Giant Pangola (*Digitaria valida* Stent)[1]

A. Sotomayor-Ríos, K. F. Schertz, R. Woodbury, and J. Vélez Fortuño[2]

INTRODUCTION

The introduction of forage species is one of the main approaches in attempting to improve forages. An introduction, Giant Pangola, a type of *Digitaria valida* Stent[3], Puerto Rico P.I. 2281, appeared to be a promising forage grass in preliminary tests of the Plant Breeding Department of the Agricultural Experiment Station of the University of Puerto Rico[4]. This grass which was introduced from Cuba is characterized by broad bright glaucous green leaves and upright growth until blooming, at which time it usually starts spreading laterally by stolons.

It has been referred to in the literature as Giant Pangola, Kob grass, and Kob Hill Digitaria (*9, 10, 11*)[5]. Giant Pangola, or its Spanish equivalent *Pangola Gigante*, is the name commonly used because it is of the same genus and resembles Pangola grass (*Digitaria decumbens* Stent) but grows taller with broader leaves.

Because of the desirable forage characteristics of Giant Pangola it appeared to be useful in a breeding program, but before a selection is used for crossing, its reproductive behavior should be thoroughly understood. Preliminary observations of low seed set raised questions about its potential for breeding. The purpose of the present study was to determine the reproductive behavior of Giant Pangola and to evaluate the possibility of using it in a breeding program. The work included a taxonomic description and species verification, a determination of fertility, and a study of the reproductive processes.

Previous reports include little about such characteristics of this species. The chromosome number of *D. valida* was reported as 24 by Young and Crocker (*12*), 30 by de Wet (*4*), and 36 by de Wet and Anderson (*5*).

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[3] Verified by Smithsonian Institution, Washington, D. C.

[4] Unpublished data.

[5] Italic numbers in parentheses refer to Literature Cited, p. 59.

Apparently nothing has been published on fertility, microsporogenesis, or megasporogenesis.

This study is of importance because of the possibility of using Giant Pangola in areas now being planted to Pangola grass which it resembles. Pangola grass is the third most important grass in Puerto Rico with an estimated 50,000 *cuerdas*[6] in cultivation, but its utilization in a breeding program is limited because of its sterility. This species with 30 chromosomes, reported by Burton (*2*) and Sheth *et al.* (*7*), has meiotic irregularities observed which account for the sterility (*7*). If Giant Pangola is sufficiently productive and possesses desirable reproductive characteristics, it might be more useful to forage breeders than Pangola grass.

MATERIALS AND METHODS

Buds for determining meiotic behavior were obtained from field plots at the Río Piedras Agricultural Experiment Station and at the Gurabo Agricultural Experiment Substation. Percentage seed set was determined from panicles of field-grown plants at these two locations.

Determinations of somatic chromosome number and analyses of meiotic behavior were made in the cytological laboratories of the Federal Experiment Station at Mayagüez. Chromosome counts were made from vigorously growing root tips removed from potted tillers. The root tips were pretreated in 1 part 0.002 M solution of 8-hydroxyquinoline and 1 part aqueous solution of α-bromonapthalene for 3 hours at 12° C. (*6*). They were then fixed in Farmer's solution and smeared in aceto-orcein by the method of Tjio and Levan 1950 (*8*).

A solution of absolute alcohol, chloroform, and glacial acetic acid in a 6:3:1 proportion, was used for fixing microsporocyte material. Smears were made with aceto-carmine, and pollen was stained in IKI solution. Material for megasporogenesis observations was fixed in CRAF, processed through paraffin and stained with haematoxylin.

EXPERIMENTAL RESULTS

DESCRIPTION

Inasmuch as Giant Pangola differed in several characters from the original description of *D. valida* (*1*), it is appropriate to include a short description of this variety.

Giant Pangola is a vigorous tufted plant reaching a height of 1 m. or more and with long, slender, hirsutulose stolons (fig. 1, A and B). The leaves are soft, glaucous, loosely villous, and of a linear shape with a length

[6] 1 *cuerda* equals 0.97 acres.

to 40 cm. and a width to 1 cm. Leaf sheaths are densely villous toward the base end at the node.

The inflorescense is digitate at the base and somewhat scattered above,

FIG. 1.—A, An experimental plot of Giant Pangola (*Digitaria valida* Stent) at the Gurabo Agricultural Experiment Substation. Plot size 30′ x 30′. B, A close-up of Giant Pangola at the Río Piedras Agricultural Experiment Station. Height to tip of leaves 20″. C, A spikelet of Giant Pangola, dorsal view, 18 ×, drawn by Julio Torres. D, A spikelet of Giant Pangola, ventral view, 16 ×, drawn by Julio Torres.

producing 6 to 11 racemes 10 to 20 cm. long and 2 mm. wide; the rachis is 1 mm. wide with a 0.3 mm. wing on either side.

Spikelets are lanceolate, 2.6 to 3 mm. long, first glume small but present, second glume two-thirds as long as the spikelet, lemma 5-nerved, 3 inner

prominent, coarsely ciliate along the second pair of nerves; palea membraneous, slightly shorter than the lemmas (fig. 1, C and D).

CHROMOSOME NUMBER AND REPRODUCTIVE BEHAVIOR

The chromosome number was found to be 42 from observations of root-tip smears (fig. 2,A) and was confirmed by chromosome counts in microsporocyte smears.

Meiotic divisions of the microsporocytes were quite irregular. Multivalent frequency during prophase was high (fig. 2,B), and at first metaphase, univalents, bivalents, trivalents, and quadrivalents were present (fig. 2,C). The mean number of bivalents was 14.5, with a maximum of 18 in one cell. The mean number of univalents, some of which were not on the metaphase

FIG. 2.—A, A smeared root tip cell of Giant Pangola with 42 chromosomes; B, prophase I of microsporocyte with multivalents of the same; C, metaphase I with univalents, bivalents, and multivalents of the same. All photomicrographs ca. 900 ×.

plate, was 4, with a maximum of 8. Only rarely was a cell seen with no multivalents at metaphase. The largest number of chromosomes in multivalent configurations was 17, 3 trivalents and 2 quadrivalents.

Anaphase I was also irregular with all cells observed at this stage possessing univalent chromosomes (fig. 3,A). In 100 cells, there was a mean of 3.8 laggards per cell, with one cell having 8. The laggards usually divided and proceeded toward the poles, but often they were not included in the nuclei at telophase and in the secondary sporocytes (fig. 3,B). Anaphase I distribution of chromosomes was often unequal with as few as 15 observed migrating toward one pole.

Lagging chromosomes were frequent at second metaphase and second anaphase, with no normal divisions observed. Microspore quartets contained many micronuclei (fig. 3,C). Of 100 quartets, all had micronuclei, with a mean number of 4.6 per spore quartet.

Most of the pollen grains were probably nonfunctional; of 1,000 grains studied only 23 (2.3 per cent) stained completely in IKI solution and these

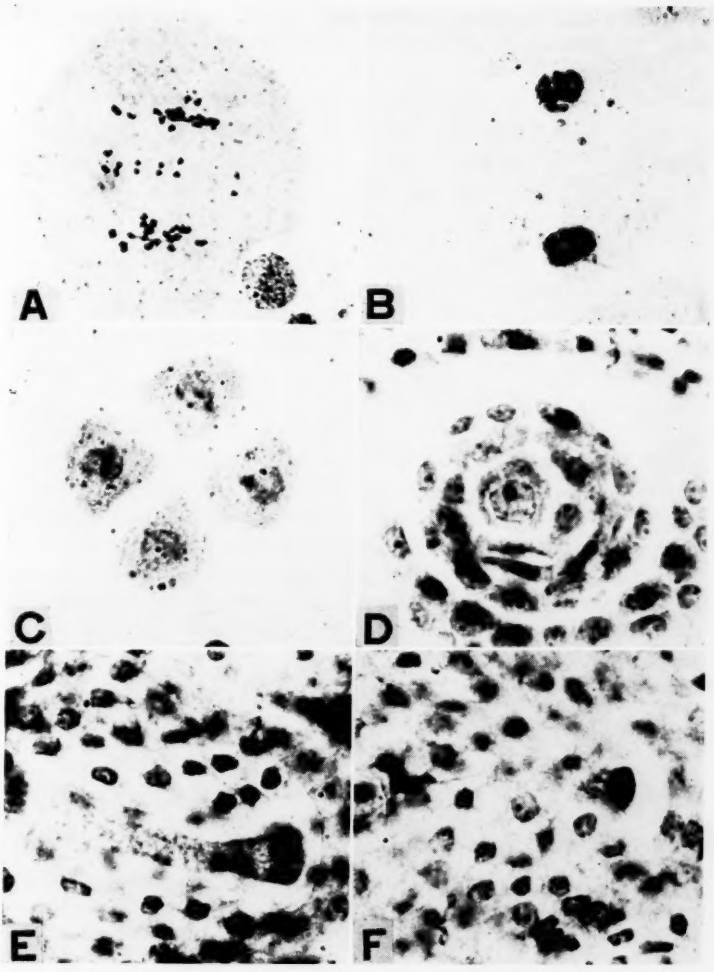

FIG. 3.—A, Late anaphase I with lagging univalents of Giant Pangola; B, secondary microsporocytes of same with micronuclei; C, microspore quartet of same with micronuclei; D, magasporocyte of same; E, megaspore of same enlarged; F, megaspore of same collapsed. All photomicrographs ca. 900 ×.

were variable in size. Eighty-four percent of the pollen grains were partly stained, and 14 percent were completely unstained. During megasporogenesis the megasporocyte enlarged (fig. 3,D) and underwent meiotic divisions forming an elongated megaspore (fig. 3,E). In most cases degenera-

tion was observed to occur after the megaspore was formed. Before meiotic divisions the megaspore collapsed (fig. 3,F); sometimes a cavity was left, but at other times it was filled by nucellar tissue. Normal megagametogenesis was infrequent and probably accounts for the karyopses which developed. Of 2,154 florets examined, 32, or 1.5 percent developed karyopses but none of the seeds germinated.

DISCUSSION

The extremely low fertility of Giant Pangola demonstrated in the studies described will limit its use in a breeding program. The constitution of 42 chromosomes is irregular for this species and may account for the abnormalities of microsporogenesis and megagametogenesis which appear to be sufficient to cause the low fertility. Since previous work (*3*, *4*, *12*) on *D. valida* cytology did not include information on meiosis or fertility, no comparison of reproductive behavior is possible.

Studies of species relationships might aid in explaining the chromosomal irregularities and might provide a clue as to the origin of Giant Pangola. It is possible that the 42 chromosome selection used in this study is an aneuploid, but its chromosome number would also fill the requirements of an euploid with a basic number of six or of seven. If it has a basic number of six it could be a 7X type (septaploid) in a series with the previously reported numbers of 24, 30, and 36 for this species. The other alternative, a basic number of seven, is uncommon in this genus, but has been reported for *D. sanguinalis* (L.) Scop. with 2N = 28 (*3*).

Studies of ovule and seed development may help to explain the lack of viability of the seeds obtained.

SUMMARY

The chromosome number and reproductive behavior of Giant Pangola, a type of *Digitaria valida* Stent, were determined to evaluate the possibility of using it in a breeding program. It was also described and verified taxonomically. The observations revealed anomalies which would appear to severely handicap its use in breeding. The somatic chromosome constitution of 42 is different from those previously reported for this species.

Microsporogenesis was irregular in all cells studied, characterized by multivalent formation, lagging univalents, and micronuclei, and resulted in only 2.3 percent of the pollen grains staining completely in IKI solution.

No degeneration was observed during megasporogenesis but was usually apparent after megaspore formation. It is concluded that the chromosomal irregularities noted may be sufficient to cause the very low seed set and that this low fertility will limit the utilization of Giant Pangola in a breeding program.

RESUMEN

Este estudio se realizó con el propósito de determinar el número de cromosomas y el comportamiento reproductivo de la yerba forrajera Pangola Gigante, un tipo de *Digitaria valida* Stent, con el fin de establecer su utilidad potencial en un programa de mejoramiento genético. Esta especie fué tambien descrita y verificada taxonómicamente.

Se encontraron 42 cromosomas somáticos cuyo número difiere de los anteriormente informados para esta especie: 24, 30 y 36.

El proceso de microsporogénesis resultó irregular en todas las células estudiadas y se caracterizó por agrupaciones multivalentes, univalentes retardados y micronúcleos. El polen tiñó completamente en solución de IKI (Ioduro de potasa iódico) en un 2.3 por ciento solamente.

No se observó degeneración durante el proceso de megasporogénesis, pero sí fué visible después de la formación de la megaspora.

Se concluye que las irregularidades cromosómicas fueron suficientes para la escasa formación de semilla obtenida y que este bajo grado de fertilidad limitará seriamente la utilización de la Pangola Gigante en un programa de mejoramiento genético.

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Maturity Indices for Pigeonpeas

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INTRODUCTION

Pigeonpeas (*Cajan cajan* L.) are grown extensively in Puerto Rico both for the fresh market and for canning. For canning operations, the pigeonpeas are purchased on a weight basis, and no objective or subjective quality indices are used to grade the raw product. As a result, the raw material entering the canneries varies in maturity from tender green to fully mature peas which makes it almost impossible to obtain uniform quality in the canned product. In order to improve the quality of the pack, it will be necessary that canners purchase the raw peas on a quality, rather than on a weight basis. To achieve this, it is necessary to establish suitable maturity indices for measuring the quality of the raw peas and to ascertain their suitability for canning.

No information has been published on the use of objective measurements to determine the maturity of pigeonpeas. However, many methods are available for measuring the maturity of peas (*Pisum sativum* L.) and field peas (*Vigna sinensis*). Makower has reviewed (*1*)[2] most of the tests in use to measure the maturity of peas. Of the several methods proposed, tenderometer readings, specific gravity, alcohol-insoluble solids, total solids, and starch content seem to be the most reliable. More recently Malcolm *et al.* (*2*) studied the suitability of these indices to measure the maturity of field peas obtaining a significant correlation between the stage of maturity and the moisture and alcohol-insoluble solids content, starch, resistance to puncturing by a penetrometer, and the percentage juice expressible by pressure.

It was assumed that pigeonpeas would follow a similar pattern of development to peas and field peas and therefore, similar indices could be used to measure the maturity. Consequently, the changes in starch, alcohol-insoluble solids, total solids, total sugars, specific gravity, and soluble-solid content during the development of the pigeonpea were studied.

[1] Respectively, Technical Director, Research Assistant in Chemistry, and Assistant Chemist, Food Technology Laboratory, Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R. The authors wish to express their gratitude to other members of the staff of the Food Technology Laboratory for the assistance and cooperation during the course of this study, and to Associate Director B. G. Capó for assistance given in the statistical interpretation of the data. Special recognition is given to R. Abrams who was in charge of the experimental plantings used in this work.

[2] Italic numbers in parentheses refer to Literature Cited, p. 69.

MATERIALS AND METHODS

SAMPLING

In the early part of this work, pigeonpeas of the "Saragateado" variety were harvested at different stages of development. Since the pigeonpeas increase in size during ripening, the fullness of the pods was used as a guide for harvesting according to the stage of development. The pods were shelled by hand and the peas grouped according to size. It was observed that the intensity of the green pigment could be used as index of maturity, as the green pigment slowly disappears during ripening. The peas were further subdivided into groups representing different stages of development as judged by the intensity of the green pigment.

Later, pigeonpeas of the Saragateado variety were harvested at different stages of development as follows: A plot of approximately 2.3 acres containing 4,148 trees was divided into 18 rows each containing about 230 trees. The rows were randomized for sampling. When the peas reached the stage of development where fully developed peas with intense green pigment were more abundant, the first two rows were harvested, all pods being picked, irrespective of the stage of development. Two rows selected at random were then harvested at intervals of 3, 6, 9, 12, 15, 20, 22, and 27 days after the first harvest. The pods from each picking were shelled by row in a Sinclair-Scott pilot-plant huller with a capacity of approximately 500 pounds of pods per hour. Representative samples of the shelled peas were taken for analysis. The numbers of undeveloped, fully developed, ripe, overripe, and dry peas were determined by count in each sample.

ANALYTICAL METHODS

Starch determination: Starch was determined by the procedure described by Carter and Neubert (*3*) for the determination of starch in apples. One hundred grams of pigeonpeas are made into a slurry with 100 ml. of water in a Waring Blendor. To 7–9 gm. of the slurry in a 50-ml. beaker, 20 ml. of 7.8 N. $HClO_4$ are slowly added with constant stirring. After standing for 10 minutes at room temperature, the mixture is transferred to a 1000-ml. volumetric flask and made to volume with distilled water, then filtered through No. 4 Whatman paper. Five milliliters of the filtered solution are transferred to a 100-ml. volumetric flask, 1 ml. of 5-percent KI sol. and 1 ml. of 0.1 N. KIO_3 solution are added and the mixture is let to stand 5 minutes to develop color, and then completed to volume. Percentage transmittance is read in a Spectronic 20 colorimeter at 620 μ, with the instrument adjusted to 100 with a blank prepared in the same way as the sample, but decolorized by the addition of two drops of 0.16 N. sodium thiosulfate. The percentage of starch is determined from a curve prepared from the spectrophotometric

readings of known concentrations of starch isolated from pigeonpeas by the procedure described by Nielsen (*4*).

Alcohol-insoluble solids: Alcohol-insoluble solids were determined by the A.O.A.C. procedure (*5*). The sample for analysis was prepared by grinding in a mortar a 50-gm. sample with 50 gm. of sand. About 30 gm. of this preparation are transferred to a 600-ml. beaker and extracted for 30 minutes with 80-percent alcohol, at gentle boiling. After the extraction is complete, the sample is filtered, the solids are washed with alcohol until the filtrate is free of coloring matter, and the washed solids are transferred to an aluminum dish and dried at 100° C. for 2 hours.

Total solids: The total solids and moisture were determined by the A.O.A.C. procedures (*6*). A representative sample of pigeonpeas is ground in a mortar, and 10–15 gm. are weighed into an aluminum dish and dried to constant weight under vacuum at 70° C.

Specific gravity: Specific gravity was measured by the method of Jodidi (*7*) modified as follows: The volume occupied by a 50- to 100-gm. sample of pigeonpeas was determined from the water displaced when the sample was added to a known volume of water in a 250-ml. cylinder.

Soluble solids: Brix; a known weight of pigeonpeas was dispersed in a known weight of water in a Waring Blendor. Soluble solids expressed as Brix were determined by the use of an Abbee refractometer at room temperature (27° C.) on a clear filtrate from the prepared dispersion. Soluble-solid contents were calculated to the original weight of the raw peas.

Total sugars as invert: Total sugars as invert were determined by the A.O.A.C. procedure (*8*). Fifty grams of pigeonpeas are made into a slurry with 50 gm. water in a Waring Blendor. Thirty grams of the slurry are weighed into a 250-ml. volumetric flask, and neutralized with $CaCO_3$. One hundred and fifteen milliliters of 50-percent alcohol are added and the solution is boiled on steam for 1 hour, using a small funnel in the neck of the flask to condense the vapors. The resulting solution is cooled and allowed to stand overnight. Neutral 95-percent alcohol to complete the volume is added, the mixture is well mixed and allowed to settle, and filtered through rapid-filtering filter paper. Two hundred milliliters of the filtrate are transferred into a 400-ml. beaker and evaporated on a steam bath to 20–30 ml. The solution is transferred to a 100-ml. volumetric flask, enough saturated neutral lead acetate solution is added to produce a flocculent precipitate, it is allowed to stand 15 minutes, diluted to mark with distilled water, and filtered. The filtrate is deleaded with Na_2CO_3 and filtered. Fifty milliliters of the prepared solution are inverted with 5 ml. of concentrated HCl at room temperature, which generally takes about 18 hours. Reducing sugars were determined after inversion by the Munson and Walker procedure (*8*).

RESULTS AND DISCUSSION

The average values for starch and alcohol-insoluble solids, specific gravity, and total solids of pigeonpeas at different stages of development, as judged by the size of the peas and the intensity of the green pigment, are

TABLE 1.—*Starch, alcohol-insoluble solids, total solids (percent), and specific gravity of pigeonpeas at different stages of development*

Stage of development	Starch	Alcohol-insoluble solids	Specific gravity	Total solids
Group A:				
Young and tender, small, intense green pigment	3.50	10.3	1.017	19.7
	3.70	11.2	1.015	19.5
	4.98	16.1	1.039	18.9
	3.90	11.2	1.037	18.5
	3.80	12.6	1.030	13.5
	5.01	13.5	1.037	18.3
	6.60	15.5	1.048	21.2
	5.20	12.1	1.050	19.7
	5.30	12.4	1.047	19.2
	6.50	12.0	1.047	19.0
Group B:				
Mature, fully developed, predominantly green, but varying in color from green to yellowish-green	6.01	14.7	1.021	22.6
	10.05	17.3	1.021	26.1
	9.80	21.6	1.048	22.7
	10.11	16.0	1.050	22.5
	8.70	20.1	1.060	33.7
	11.30	21.8	1.064	24.9
	11.20	22.3	1.071	27.4
	10.70	19.5	1.076	27.6
	13.10	20.3	1.057	25.6
	13.40	22.9	1.072	26.3
Group C:				
Overripe, yellowish-green to almost completely devoid of green pigment	12.2	20.0	1.081	29.6
	14.8	23.3	1.083	29.0
	16.1	31.8	1.082	27.9
	16.7	26.1	1.100	22.1
	18.9	25.0	1.120	46.9
	18.2	27.5	1.140	31.1
	20.2	29.1	1.125	33.2
	19.85	25.0	1.083	30.5
	18.90	26.1	1.098	31.6
	19.10	31.6	1.098	32.7

given in table 1. Results of the statistical analyses of these data are shown in table 2; these show that the starch, the alcohol-insoluble solid content, the specific gravity, and the total solids increased as the pigeonpeas mature. Significant differences in starch, alcohol-insoluble solids, and total solids

were found among the three groups studied. A significant difference was found in the specific gravity between groups A and C, and between groups B and C, but not between groups A and B.

These results indicate that the starch, alcohol-insoluble solids, and total solids of pigeonpeas are adequate objective indices of maturity, while the specific gravity is not too reliable. The fact that the specific gravity in-

TABLE 2.—*Statistical analysis of data given in table 1*

Item	Mean values for groups—			Least significant difference between two means at—		Remarks
	A		C	5 percent P	1 percent P	
Percentage starch	4.849	10.482	17.495	2.61	3.52	Significant difference between groups at 1 percent P.
Percentage alcohol-insoluble solids	12.69	19.65	26.55	3.81	5.15	Do.
Specific gravity	1.0367	1.0530	1.101	.02290	.03092	Significant difference between groups A and C and B and C at 1 percent P. No significant difference between groups A and B.
Total solids	18.7	25.95	32.09	5.047	6.816	Significant difference between groups A and B and A and C at 1 percent P. Significant difference between group B and C at 5 percent P.

creased as the pea matured led us to regard these results with suspicion. It is probable that the failure to obtain a significant difference between groups A and B was attributable to experimental error, and to the lack of precision of the method employed for measuring the specific gravity. Since the specific gravity determination is made by measuring the volume of water displaced by a known weight of pigeonpeas, the presence of air bubbles and moisture in the sample affects the determination. Young, tender peas are usually wet and, when immersed in water, many air bubbles can be seen adhering to their surface, which may lead to a fairly great experi-

mental error when the method of volume displacement is used to measure the specific gravity at this stage of development.

Since pigeonpeas possess undetermined fruiting characteristics it is common to find peas at all stages of development, even on the same shrub. During harvesting, it is almost impossible to pick only peas at a certain stage of development, and, consequently, it is to be expected that the commercial produce will be a heterogeneous mixture of peas at many stages of development. Objective indices to be used for measuring the maturity of pigeonpeas should be capable of indicating differences between the heterogeneous mixtures at different intervals throughout the crop. If this is not possible, the use of objective maturity indices already discussed will be useless in the commercial harvesting of the crop.

TABLE 3.—*Percentages of pigeonpeas tested which were at different stages of development*

Type of peas	Percentage at indicated time interval between harvest in days								
	0	3	6	9	12	15	20	22	27
Small and undeveloped	25.5	9.5	16.5	10.5	16.5	14	5	14	7
Large, mature, green	72	90	78	80	67	62	49	48.5	44
Large, ripe, yellow color	0	.5	2	7	10.5	13	24	13.5	14.5
Dry	2.5	0	3.5	2.5	6	11	22	24	34.5

In order to test whether the objective indices already proved to show difference in maturity are suitable for indicating the maturity of the peas when harvested commercially, the pigeonpeas from 18 randomized plots were harvested at internals of 3, 6, 9, 12, 15, 20, 22 and 27 days after the first picking, as described under "Sampling." In order to have a sample of pigeonpeas representing the whole plantation, pickers were instructed to pick all pods irrespective of the stage of development. When shelled, the sample consisted of a mixture of young tender peas, developed peas with intense green pigment, turning peas with greenish-yellow color, ripe peas completely devoid of green pigment, and dry peas. Although it is true that dry pods are not picked in commercial practice, it was decided to pick these as well in order to reduce any bias which might have been introduced by selective picking.

The number of peas at each stage of development for each harvest is given in table 3. It should be noted that the percentage of undeveloped peas was much higher in the first picking than in the last, while the percentage of yellow and dry peas increased from the 9-day harvest interval to the last picking. Using the intensity of the green pigment as a visual

TABLE 4.—*Physical and chemical characteristics of pigeonpeas harvested at 3-day intervals for a period of 27 days*

Characteristic measured	Data for time interval between harvest days indicated								
	0	3	6	9	12	15	20	22	27
Percentage alcohol-insoluble solids	19.65	19.49	23.08	25.56	27.20	30.72	34.96	33.63	42.14
Percentage starch	10.20	11.30	13.30	14.40	14.85	16.90	19.75	19.15	20.70
Percentage total solids	24.0	25.5	28.5	31.0	28.75	38.0	42.75	43.75	46.50
Percentage total sugars as invert	2.42	2.75	1.95	1.90	2.46	—	3.06	2.17	3.01
Soluble solids—°Brix	8.1	13.4	11.0	9.90	10.70	16.5	14.40	19.1	26.80
Specific gravity	1.1010	1.0830	1.071	1.1026	1.1292	1.1405	1.1465	1.1442	1.1688
Percentage of fully developed green peas	72.0	90.0	78.0	80.0	67.0	62.0	49.0	48.5	44.0

index of maturity, it can be concluded that the number of ripe peas, including the dry ones, increases with crop length. It is reasonable to expect that the starch and alcohol-insoluble solids, the total solids, and the specific gravity will increase progressively from the first to the last crop, and if these measures are adequate maturity indices, it should be possible to obtain a significant correlation between any of these values and the intensity of the green pigment.

The values obtained for starch, alcohol-insoluble solids, total solids, specific gravity, total sugar as invert, and the soluble solids as Brix, are given in table 4. It will be observed that, as expected, there is an approximately progressive increase in the starch, alcohol-insoluble solids, total solids, and specific gravity from the first to the last crop. It should also

TABLE 5.—*Correlation between percentage of fully developed green pigeonpeas and proposed objective indices*

Index	Range of values measured	Coefficient of correlation value		
		Experimental	At 5-percent level	At 1-percent level
Percentage alcohol-insoluble solids	19.65 –42.14	−0.9143	0.666	0.798
Percentage starch	10.20 –20.70	−.9458	.666	.798
Percentage total solids	72.00 –44.0	−.9043	.666	.798
Percentage total sugar as invert	2.42 – 3.06	−.4577	.707	.834
Soluble solids—°Brix	8.1 –26.8	−.0939	.666	.798
Specific gravity	1.071– 1.1688	−.9234	.666	.798

be noted that the change in the total reducing sugars and the soluble solids followed no definite pattern.

The correlation coefficients obtained from correlating the values of the proposed objective indices and the percentage of fully developed green peas are given in table 5. Correlation coefficients significant at 1-percent P. were obtained for starch, alcohol-insoluble solids, total solids, and specific gravity. No significant correlation was obtained between total sugars as invert and percentage of green peas, nor between soluble solids or degree Brix and green peas.

As may be seen from the values in tables 4 and 5, total solids, percentage of starch, alcohol-insoluble solids, and specific gravity, are good indices of maturity for pigeonpeas. For precise laboratory-control work the alcohol-insoluble-solids determination, although time-consuming, is to be preferred, as it is more consistent, and reproducible results can be obtained. Although the starch content is a good indication of maturity, the method is subject

to many errors which may lead to inconsistent results. Extreme care must be taken to completely solubilize the starch and avoid hydrolysis; otherwise, low starch values may be obtained.

Since total solids and moisture are intimately related, moisture content may be used instead of using total solids as a maturity index. In this case, it should be remembered that the moisture content of pigeonpeas varies inversely with maturity, beging higher for tender and lower for mature peas. With the new infrared moisture-determination balances available, a moisture determination can be performed in a relatively short time, so the moisture content may prove to be an adequate index for routine determinations. Malcolm *et al.* (*2*) compared the A.O.A.C. vacuum-oven method with the infrared method for the determination of moisture in field peas, and concluded that the latter was less variable when replicate samples were compared. Similar results were obtained in this work when the A.O.A.C. vacuum-oven method was compared with the infrared method, using the infrared moisture-determination balance.

The specific-gravity determination, although less precise than the others, may be used as a field test for the determination of the maturity of pigeonpeas. In using this method it should be remembered that moisture in the sample and air under the skin, as well as the size of the sample, may introduce a large error which can result in failure to detect small differences in specific gravity.

SUMMARY

When pigeonpeas mature, there is an increase in the starch, alcohol-insoluble solids, and total-solids contents, and in the specific gravity, and a decrease in the intensity of the green pigment. A high correlation was obtained between the intensity of the green pigment and starch, alcohol-insoluble solids, total solids, and specific gravity. A high correlation was also obtained between the number of green peas in a heterogeneous sample containing peas at different stages of development and all of the above-mentioned measures. Any of these measurements can be used as a maturity index for pigeonpeas. Since the moisture content is directly related to the total solids, moisture can also be used as a suitable and reliable maturity index.

RESUMEN

Cuando el gandur madura, su contenido de almidón, sus sólidos insolubles en alcohol, sus sólidos totales y su gravedad específica aumentan gradualmente, mientras que el pigmento verde disminuye. Se ha encontrado que existe una correlación significativa entre la intensidad del pigmento verde y cada una de las condiciones del grano antes indicadas. Ha sido posible

también establecer una correlación, altamente significativa, entre el número de granos verdes en una muestra heterogénea que contiene gandures en distintas etapas de desarrollo, con el contenido de almidón, los sólidos solubles en alcohol, los sólidos totales y la gravedad específica. Se ha demostrado además, que cualquiera de estas medidas puede usarse como índice de madurez para indicar el estado de desarrollo del grano. Como el contenido de humedad y los sólidos totales están íntimamente relacionados, la primera de estas medidas puede usarse también como un índice de madurez.

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Effects of Growth Regulators on the Rooting of Grape Cuttings[1]

A. Pérez López and R. Abrams[2]

INTRODUCTION

Grapes have been grown in Puerto Rico ever since the early colonization days. They were brought and planted by Spanish settlers in patios and gardens for home consumption. Vines producing fair to good yields can be seen today growing around the Island.

As a possible means of diversifying the fruit industry in Puerto Rico grapes are being tested in search of types of good commercial value and productivity adapted to our conditions. The purpose of this study was to determine possibilities and usefulness of propagating grapes by treating cuttings with growth regulators.

MATERIALS AND METHODS

For this study, 15- to 25-cm. cuttings, including three nodes of cane wood, were taken from portions of the previous season's growth. The grape variety used was Florida Selection 1001. The cuttings were treated with the powdered form of commercial preparations of two root-inducing substances. One contained 0.3 percent of indolebutyric acid and the other 0.10 percent of naphthylacetamide, 0.05 of 2 methyl 1 naphthylacetic acid, and 0.02 of 2 methyl 1 naphthylacetamide. In this paper the letters IBA and NAA are used, respectively, for reference to these substances. The leaf areas of cuttings were kept at a maximum.

The treatments consisted of moistening the basal ends of the cuttings and immersing them in the appropriate hormone powder to a depth of 1 inch. The cuttings were placed in a shedhouse receiving 80-percent natural light. They also received an 8-second-per-minute overhead mist spray during the daylight hours.

The experimental design was a split-plot one in which the two hormone treatments and the control were studied in the whole plots. A subplot consisted of 20 cuttings, set 1½-inches deep in holes previously made in fumigated sand beds. The spacing was 2 inches between cuttings and 4 inches between rows. The cuttings were dug from the sand beds at 6-, 8-, and 10-week intervals, and records were taken for each treatments of the percent-

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age of rooted cuttings, number of roots per cutting, and length of roots in centimeters. All treatments were replicated four times.

RESULTS

EFFECT OF ROOT-INDUCING SUBSTANCES ON THE ROOTING OF THE CUTTINGS

Data on the percentage of rooted grape cuttings treated with the root-inducing substances and left in the sand beds for 6, 8, and 10 weeks are presented in table 1.

The mean rooting percentages for the control, IBA, and NAA treatments were 62.42, 47.92, and 40.00, respectively, the differences among which were not significant.

TABLE 1.—*Mean rooting percentages of grape cuttings treated with root-inducing substances and left in sand beds for 6, 8, and 10 weeks*

Treatments	Rooted cuttings after number of weeks indicated			
	6	8	10	Mean
Control	38.50	63.75	85.00	62.42
IBA	26.25	57.50	60.00	47.92
NAA	15.00	45.00	60.00	40.00
Mean	26.58	55.42	68.33	50.11

EFFECT OF DIFFERENCES IN PERIOD IN SAND BED

The results of the effect of the differences in time interval during which cuttings were in the sand bed on the rooting of grape cuttings are also presented in table 1. There were highly significant differences between the time intervals used in this experiment; the longer the time that the cuttings remained in the sand beds the higher the rooting percentages, regardless of the hormone treatment. The 10-week interval was significantly superior in this respect at the 1-percent level to the 6- and 8-week intervals, indicating that this is the best period of the three tested to leave the cuttings in the sand beds in order to get the best rooting percentage. The mean rooting percentages for the 6-, 8-, and 10-week intervals were 26.58, 55.42, and 68.33, respectively.

Regardless of the hormone treatments, the cuttings left in the sand beds for a 10-week period had a higher rooting percentage than those left for 6 and 8 weeks. These results were also significant at the 1-percent level.

The standard errors and least differences for significance between mean rooting percentages are shown in the following tabulation:

Comparison	*5 percent*	*1 percent*
Hormone treatments		
Difference between highest and lowest means	41.21	60.01
Difference between 2 adjacents	32.85	49.75
Standard error: 9.50 with 6 d.f.		
Time intervals		
Difference between highest and lowest	9.75	12.69
Difference between 2 adjacents	8.02	10.99
Standard error: 2.70 with 18 d.f.		
Between time intervals for same hormone treatments		
Difference between highest and lowest	16.89	21.99
Difference between 2 adjacents	13.90	19.05
Standard error: 4.68 with 18 d.f.		
Between any 2 hormones for same time intervals		
Difference between highest and lowest	42.50	61.04
Difference between 2 adjacents	33.98	50.92
Standard error 10.02		

AVERAGE NUMBER OF ROOTS PER CUTTING

Table 2 and figure 1 show the effect of root-inducing substances on the number of roots per cutting. Treating the cuttings with IBA definitely

TABLE 2.—*Mean number of roots per cutting of grapes treated with root-inducing substances and left in sand beds for 6, 8, and 10 weeks*

Treatments	Roots per cutting after number of weeks indicated			
	6	8	10	Mean
IBA	7.09	6.05	10.65	7.93
Control	5.02	5.25	5.09	5.12
NAA	3.45	4.46	5.58	4.49
Mean	5.18	5.25	7.10	5.84

increased the number of roots per cutting; however NAA had no effect. These findings on the number of roots due to indolebutyric acid agree with previous work done on grapes by Cowart and Savage (*2*),[3] Harmon (*3*), and Sharpe (*4*). Abrams and Jackson (*1*), working with acerola cuttings treated with indolebutyric acid, found that these produced a larger number of roots than those treated with naphthaleneacetic acid and the control. Therefore, the use of indolebutyric acid is justified from the standpoint of the survival of rooted grape cuttings.

[3] Numbers in parentheses refer to Literature Cited pp. 76.

Leaving the cuttings in the sand beds for 10 weeks effected a significant difference over 6 and 8 weeks in the number of roots produced. There was no significant difference between 6- and 8-week intervals, indicating that 10 weeks is the optimum period for producing a larger number of roots.

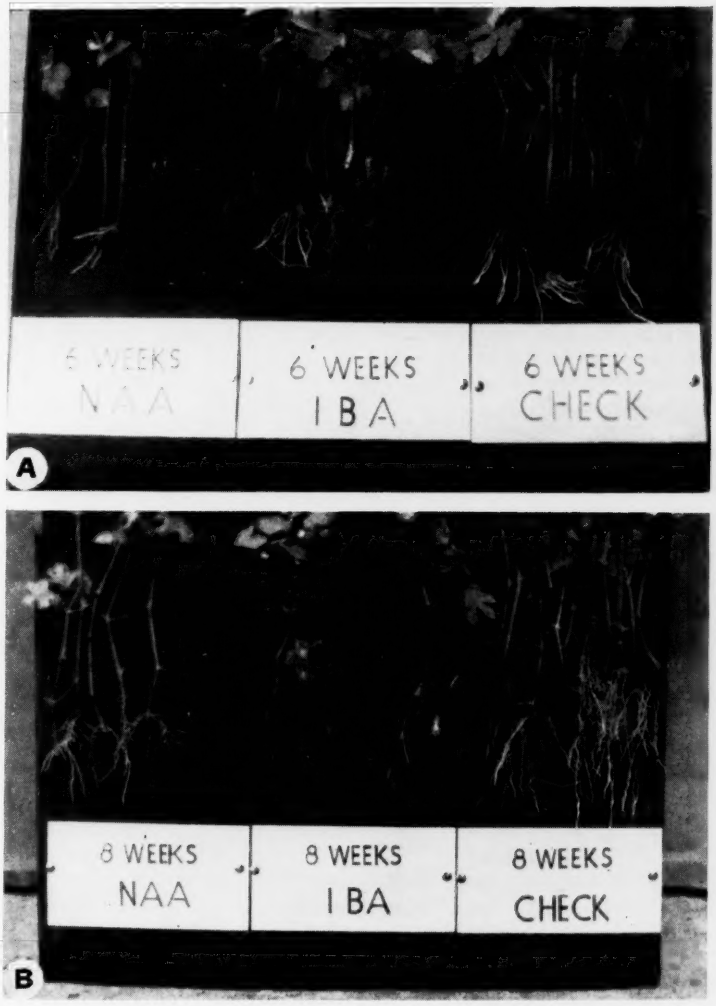

FIG. 1.—The effect of root-inducing substances on the rooting of grape cuttings: A, 6 weeks after planting and B, 8 weeks after planting.

The mean number of roots for the 6-, 8-, and 10-week intervals was 5.18, 5.25, and 7.10 roots per cutting, respectively.

The standard errors and least differences for significance between mean number of roots per cutting are shown in the following tabulation:

Comparison	*5 percent*	*1 percent*
Hormone treatments		
Difference between highest and lowest	1.07	1.55
Difference between 2 adjacents	.85	1.29
Standard error: 0.25 with 6 d.f.		
Time intervals		
Difference between highest and lowest	1.61	2.09
Difference between 2 adjacents	1.32	1.81
Standard error: 0.45 with 18 d.f.		
Between time intervals for same hormone treatments		
Difference between highest and lowest	2.78	3.62
Difference between 2 adjacents	2.29	3.13
Standard error: 0.77 with 18 d.f.		
Between any 2 hormones for same time interval		
Difference between highest and lowest	2.50	3.32
Difference between 2 adjacents	2.05	2.86
Standard error: 0.68		

LENGTH OF ROOTS

The results on the average length of the roots of grape cuttings treated with root-inducing substances and left in the sand beds for 6-, 8-, and 10-weeks are presented in table 3. There were no significant differences between the effects of the hormone treatments on the average root length of the grape cuttings. Cuttings left in the sand beds for 8 and 10 weeks had longer roots than those left for 6 weeks. These differences were found to be highly significant, *i.e.*, the average root length increased consistently with the time that the cuttings were left in the sand beds.

TABLE 3.—*Mean length (centimeters) of roots of grape cuttings treated with root-inducing substances and left in sand beds for 6, 8, and 10 weeks*

Treatments	Root length after number of weeks indicated			
	6	8	10	Mean
IBA	5.30	7.14	9.65	7.36
NAA	2.83	6.60	9.96	6.46
Control	4.09	6.58	7.90	6.19
Mean	4.07	6.77	9.17	6.67

The standard errors and least differences for significance between mean lengths of roots are shown in the following tabulation:

Comparison	*5 percent*	*1 percent*
Hormone treatments		
Difference between highest and lowest	2.07	3.01
Difference between 2 adjacents	1.65	2.50
Standard error: 0.48 with 6 d.f.		
Time intervals		
Difference between highest and lowest	2.03	2.64
Difference between 2 adjacents	1.67	2.29
Standard error: 0.56 with 18 d.f.		
Between time intervals for same hormone treatment		
Difference between highest and lowest	3.52	4.58
Difference between 2 adjacents	2.89	3.96
Standard error: 0.97 with 18 d.f.		
Between any 2 hormones for same time interval		
Difference between highest and lowest	3.52	4.76
Difference between 2 adjacents	2.87	4.06
Standard error: 0.93		

DISCUSSION

The results of this study did not indicate that IBA and NAA have any significant influence on the rooting percentage of grape cuttings. However, the cuttings do respond to treatment with indolebutyric acid as to the number of roots produced. These results are partly in accordance with those of Cowart and Savage (*2*) and Harmon (*3*), who reported that indolebutyric and naphthaleneacetic acids apparently stimulated root promotion in grape cuttings, as judged by the number and quality of the roots formed. Cowart and Savage (*2*) reported that propagation of grapes by cuttings is not encouraged, but in this experiment it was found that 85 percent of the cuttings in the control treatment rooted when they were left in the sand beds for 10 weeks. This tends to indicate that the time the cuttings are left in the sand beds has a greater effect on the rooting of grape cuttings than the root-inducing substances.

SUMMARY

The effects of root-inducing substances and time intervals were studied on the rooting of grape cuttings of Florida Selection 1001 left in sand beds 6, 8, and 10 weeks. Observations were made on the number of rooted cuttings, and the number and length of roots per cutting. The major results were as follows:

1. Root-inducing substances had no significant effect on the rooting percentage of grape cuttings.

2. The time the cuttings remained in the sand beds did have highly significant effects on the rooting percentages and on the number and length of roots per cutting, regardless of hormone treatments.

3. In these respects the 10-week period was better than the 6- or 8-week periods.

4. Indolebutyric acid had the greatest effect on the number of roots produced by grape cuttings, which is of importance in the establishment of these cuttings.

RESUMEN

El efecto de hormonas de crecimiento e intervalos de tiempo se estudió en este experimento con relación al arraigo de esquejes de uvas parras. Los resultados fueron como sigue:

1. Las hormonas de crecimiento no surtieron efectos significativos sobre el porcentaje de esquejes que arraigaron.

2. El tiempo que se dejaron los esquejes en la arena demostró tener influencia significativa sobre el porcentaje de esquejes que arraigaron, así como en el número y longitud de las raíces en cada uno, independientemente del tratamiento de hormonas que recibieran.

3. El tratamiento de diez semanas resultó mejor que el de 6 y 8, en cuanto a dejar los esquejes en la arena.

4. El ácido indolebutírico aumentó el número de raíces por esqueje, lo cual es de importancia para el arraigo de estos esquejes.

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Effects of Nitrogen Fertilization and Grass Species on Soil Physical Condition in Some Tropical Pastures[1]

José Vicente-Chandler and Servando Silva[2]

INTRODUCTION

Soil compaction by livestock may become a serious problem in some soils as stocking rates are increased by heavy fertilization and pasture management is intensified. In the studies described in this paper, for instance, 2 to 3 head were carried per acre the year around. Yet, there are few quantitative data on changes caused in the physical condition of pasture soils by grazing animals. The authors have found no quantitative evaluation of nitrogen fertilization or forage species on soil compaction by grazing animals.

Keen and Cashen (*6*)[3] found that soil penetrability to a pointed rod decreased by trampling while Edmond (*3*) reported that soil-moisture content was decreased by trampling. Lieth (*7*) found that pore volume increased with decreasing trampling. Tanner and Mamoril (*8*) showed that many pasture soils suffer compaction by animal traffic which may decrease yields, while Heinonen (*4*) found that dense vegetation prevented excessive compaction in pastures.

The purpose of the present study was to measure: 1, The effect of nitrogen fertilization rates applied to Napier, Guinea, Pangola, and Para grasses on soil physical condition in small grazed plots on Catalina clay in the humid mountains of Puerto Rico; and, 2, the effect of the first three grasses on soil physical condition in heavily fertilized, intensively managed pastures on both this soil and on irrigated Santa Isabel silty clay loam on the semiarid south coast.

MATERIALS AND METHODS

SMALL-PLOT EXPERIMENT

The plots of the experiments reported by Caro, Vicente, and Figarella (*2*) were used in the present study. The main plots were used to compare the effects of cutting versus grazing management. These were split into

[1] This work was carried out cooperatively between the U. S. Department of Agriculture and the Agricultural Experiment Station of the University of Puerto Rico.

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[3] Italic numbers in parentheses refer to Literature Cited, p. 86.

plots of Napier, Guinea, Para, and Pangola grasses, which, in turn, were split into 10- x 20-foot plots receiving nitrogen at rates varying from 0 to 800 pounds per acre yearly. All treatments were replicated four times.

The experiment was carried out at Orocovis, which has a mean annual temperature of about 75° F., with a seasonal variation of less than 10° F. Annual rainfall averaged about 83 inches. The surface 6 inches of this Catalina clay, a deep, red lathosol on 30-percent slopes, had 4.5 percent of organic matter; a pH of 5.3; 16.5 m.e. of exchange capacity; and 10.4 m.e. of exchangeable bases per 100 gm. of soil.

The soil was limed to about pH 6.5 and blanket additions of phosphorus and potassium were made at the rate of 200 pounds of P_2O_5 from 20-percent superphosphate per acre in one annual application, and 400 pounds of K_2O from KCl per acre yearly in nine equal applications. Nitrogen was applied as ammonium sulfate in nine equal applications yearly.

The plots that had been grazed by livestock at 40-day intervals for 2½ years were sampled. Three undisturbed 3- x 3-inch soil cores were taken with a Bradfield sampler at 0–3- and 3–6-inch depths in all plots of the grasses receiving 0 and 800 pounds of nitrogen per acre yearly.

LARGE-SCALE GRAZING EXPERIMENTS

Adjacent, heavily fertilized (500 pounds of 14-4-10 fertilizer applied per acre every 2 months), intensively managed 1-acre experimental pastures of Napier, Guinea, and Pangola grasses, also on Catalina clay, and which had been grazed for 18 consecutive months with 2½ head per acre, were also studied. Eight cores were taken at 0–3- and at 3–6-inch depths in plots of each grass.

Similarly fertilized, intensively managed, 1-acre experimental pastures of these three grasses on level, Santa Isabel silty clay loam, that had been grazed for 18 consecutive months at the rate of 3 head per acre, were also sampled. Rainfall averaged only about 35 inches yearly and was supplemented by frequent irrigation. This soil had a pH of 7.5; 2.1 percent of organic matter; and an exchange capacity of 37.5 m.e. per 100 gm. of soil saturated with bases. Four cores were taken at 0–3- and at 3–6-inch depths in pastures of each grass.

SOIL ANALYSIS

The soil cores were weighed and then slowly saturated with water in a vacuum for several days. Percolation rates were determined by recording the rate at which water moved through the cores at a known head. Volume of large, quickly drained pores was determined by placing the soil cores in a Buckner funnel, setting a 60-cm. tension, and measuring the water removed after 15 minutes. The water removed at 60-cm. tension was meas-

ured by bringing the cores to equilibrium with this tension and determining their loss in weight. Water retained at ½ and 15 atmospheres of pressure was determined using pressure plates. Available water was taken to be that retained between ½ and 15 atmospheres of pressure. The cores were finally dried in the oven at 110° C., and bulk density was calculated by dividing their dry weight by the original volume. The pore space was calculated using a specific gravity of 2.65 as determined for this soil by Vicente-Chandler, *et al.* (*9*).

There was essentially no swelling of the cores while being saturated with water in the laboratory and, therefore, errors caused by this phenomenon were largely avoided. The fact that average maximum saturation values for the cores of Catalina clay, 62.3 percent, were almost identical with the calculated pore-space values, 62.5 percent, shows how little swelling occurred.

It is important to note that in all experiments the land was plowed repeatedly to a depth of 8 inches before the grasses were planted, presumably making this layer homogenous, and that the samples were taken 3 days after prolonged drenching rains when the soil was presumably at field capacity.

The volume of large pores is considered the best estimate of soil compaction with percolation rates and bulk densities as supporting evidence.

RESULTS AND DISCUSSION

EFFECT OF TRAMPLING ON SURFACE SOIL

A comparison of values for the 0–3- and the 3–6-inch depths in table 1 and figure 1 shows that, in the upper layer, volume of quickly drained pores was 42-percent less, volume of pores drained at 60-cm. tension 31-percent less, and percolation rates only about one-fourth as high as in the lower layer. Bulk density also averaged higher in the upper layer.

The data in table 1 show that compaction was largely confined to the upper 3 inches of soil, since values for the 3–6-inch layer under heavily fertilized Pangola grass harvested by cutting, which can be considered representative of untrampled soil, are similar to those for the 3–6-inch layer of the grazed plots. Therefore, a fairly accurate measure of soil compaction by grazing animals under these conditions can be obtained by comparing physical data for the upper and the 3–6-inch layers, particularly since the soil was initially well mixed by plowing.

Table 2 shows that trampling by grazing animals also generally caused some compaction of the upper 3 inches of soil in the large, intensively managed pastures on both soil types. Under all three grasses on Santa Isabel soil and with Guinea and Napier on Catalina, volume of pores

TABLE 1.—*The effect of grass species and nitrogen fertilization on soil physical condition at 2 depths under pastures of 4 grasses on Catalina clay after 2½ consecutive years of grazing*[1]

Grass species and N applied per acre yearly	Bulk density	Saturated percolation rate	Quickly drained pores[2]	Pores drained at 60-cm. tension	Moisture retained at ⅓ atmosphere	Moisture retained[3] at 15 atmospheres	Available water-holding capacity	Actual field capacity[3]
			0″ to 3″ depth					
		Inches per hour	*Percent*[4]	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Pangola								
0 N	1.02	3.1	3.7	6.5	48.9	35.9	13.0	53.3
800 lb. N	1.03	10.4	4.9	9.0	48.7	35.6	13.1	51.1
Guinea								
0 N	1.02	6.1	4.7	7.5	44.9	34.0	10.9	51.8
800 lb. N	1.04	2.0	4.7	7.8	48.9	36.5	12.4	51.3
Para								
0 N	1.03	10.7	4.8	7.8	47.5	33.1	14.4	49.8
800 lb. N	.98	9.0	5.5	8.1	46.8	35.1	11.7	51.2
Napier								
0 N	.99	5.7	5.6	7.5	48.0	38.5	9.5	50.0
800 lb. N	.94	12.4	7.1	9.2	45.8	36.4	9.4	50.5
Average	1.01	7.4	5.1	8.0	47.4	35.6	11.8	51.0
			3″ to 6″ depth					
Pangola								
0 N	0.95	18.9	7.7	12.1	46.7	35.1	11.6	48.5
800 lb. N	.98	30.8	10.0	13.8	44.1	35.3	8.8	43.5
Guinea								
0 N	.96	13.8	8.2	11.1	44.3	35.3	9.0	49.4
800 lb. N	.97	31.5	10.5	12.9	45.2	34.2	11.0	43.6
Para								
0 N	.98	28.5	6.9	8.8	44.0	37.6	6.4	47.3
800 lb. N	.98	49.3	9.7	12.0	44.1	37.5	6.6	45.6
Napier								
0 N	.96	21.1	7.6	10.1	47.1	39.6	7.5	49.8
800 lb. N	.94	33.6	9.4	11.7	44.8	37.0	7.8	48.1
Average	0.97	28.4	8.8	11.6	45.1	36.5	8.6	47.0
3″ to 6″ under ungrazed Pangola with 800 lb. N	0.93	31.0	10.0	14.3	44.8	38.1	6.7	

[1] All values are averages of 12 samples taken in 4 replicate plots with each treatment.

[2] Pores drained after 15 minutes at tension of 60 cm. of water.

[3] Cores taken 3 days after drenching rains.

[4] All values for moisture are shown in percentage by volume.

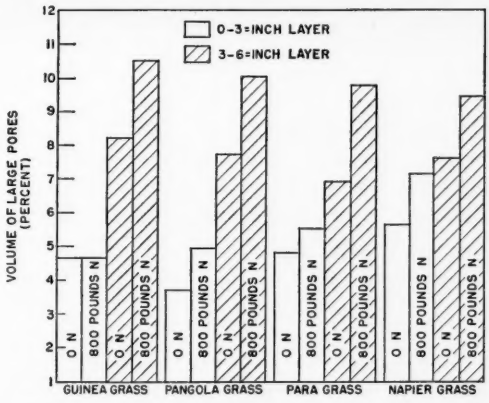

FIG. 1.—The effect of nitrogen fertilization of 4 grasses growing in Catalina clay on soil compaction by livestock over 2½ years, as evidenced by volume of large pores.

TABLE 2.—*Physical condition at 2 depths in 2 soils under heavily fertilized, intensively managed pastures of 3 grasses after 18 consecutive months of grazing*[1]

Grass	Bulk density at—		Volume of pores drained at 60-cm. tension at—		Saturated percolation rate at—	
	0"–3"	3"–6"	0"–3"	3"–6"	0"–3"	3"–6"
			Catalina clay			
			Percent	*Percent*	*Inches per hour*	*Inches per hour*
Pangola	1.04	1.04	11.3	12.2	16.2	29.0
Guinea	1.10	1.00	9.7	13.3	3.0	32.4
Napier	1.04	1.05	8.8	10.0	12.1	47.0
			Santa Isabel silty clay loam			
Pangola	1.36	1.33	8.1	11.8	—	—
Guinea	1.43	1.25	8.5	15.6	—	—
Napier	1.40	1.31	9.5	12.6	—	—

[1] Values for Catalina soil are averages of 8 replicates, those for Santa Isabel of 4 replicates.

drained at 60-cm. tension was significantly less in the upper 3 inches than in the second 3. Percolation rates were also significantly lower in the upper 3 inches of Catalina clay with all except Pangola grass. Bulk density of the upper 3 inches of soil was significantly higher under Guinea and Napier

grasses on the Santa Isabel silty clay loam and under Guinea on the Catalina clay.

It is emphasized, however, that while grazing resulted in marked change in some of the measured physical properties, none of them fall within the range that would be considered unfavorable for crop production.

Table 3 shows that the limited compaction caused by trampling did not decrease forage yields. The plots of Guinea, Napier, and Pangola grasses grazed throughout the course of the experiment actually produced higher residual yields than those harvested by simulated grazing and hence essentially untrampled.

TABLE 3.—*Yields of the 4 grasses produced over a residual 60-day period by the plots actually grazed by livestock during the small-plot experiment and by those with simulated grazing and hence essentially untrampled*

Grasses	Pounds of dry forage per acre	
	Grazed	Ungrazed
Para	5,000	5,600
Guinea	5,600	4,800
Napier	6,300	5,500
Pangola	6,900	6,200

EFFECT OF SOIL COMPACTION ON AVAILABLE WATER

Table 1 shows that the compacted upper layer of Catalina clay retained significantly more moisture at actual field capacity and at ½ atmosphere and, since moisture retention at 15 atmospheres was not appreciably affected by compaction, had a significantly higher available water-holding capacity. Jamison (*5*) has also reported increases in available water-holding capacity with compaction.

Figure 2 shows that as the volume of large pores were decreased by compaction, the available water-holding capacity of Catalina clay increased markedly, as did the actual field capacity also. For example, by decreasing the volume of large pores from 12 to 8 percent, the available water-holding capacity was more than doubled from about 6.5 to 14 percent. This means that about 0.22 inch more water could be stored for plant use in the upper 3 inches of soil. This may favor plant growth on this very porous soil which retains a high percolation rate and desirable proportions of large pores for aeration when compaction is moderate as it is under heavily fertilized grasses.

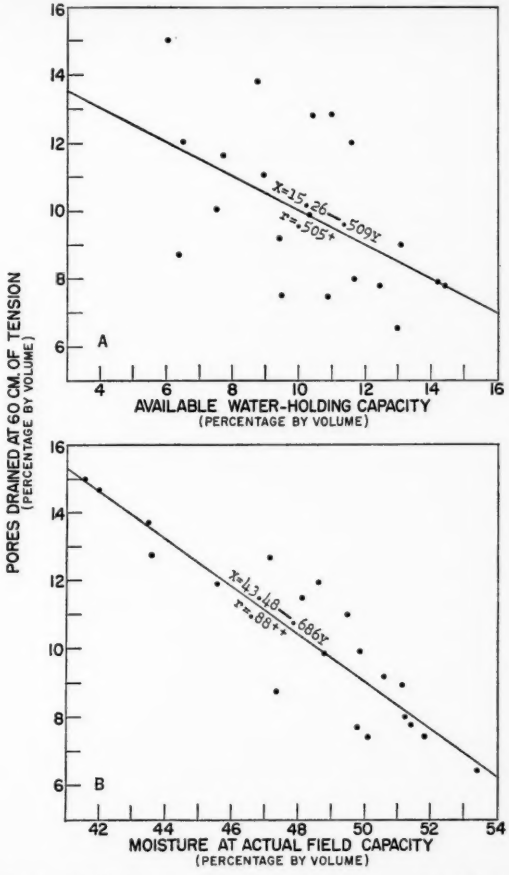

FIG. 2.—Relationship between pores drained at 60 cm. of tension and available water-holding capacity (A) and actual field capacity (B) in a Catalina clay soil.

EFFECT OF NITROGEN FERTILIZATION ON SOIL PHYSICAL CONDITION

Nitrogen fertilization of the grasses reduced compaction of the surface of Catalina clay under all grasses except Guinea (table 1 and fig. 1). The application of 800 pounds of nitrogen per acre yearly resulted in the following differences in the upper 3 inches of soil: 1, A significant increase in the volume of quickly drained pores with Para, Pangola, and Napier grasses; 2, a significant increase in the volume of soil pores drained at 60-cm. tension

with Pangola and Napier grasses; 3, a marked increase in percolation rates with Pangola and Napier grasses, and 4, a significantly lower bulk density under Para and Napier grasses. The reduction in surface-soil compaction due to heavy nitrogen applications may be explained by greater vegetative cover and root development accompanying the tremendous increases in forage yields reported by Caro, Vicente, and Figarella (*2*).

That nitrogen fertilization did not affect surface-soil condition under Guinea grass, although forage yields were increased tremendously, is explained by the fact that this grass grows in clumps with bare soil between, where the soil cores were perforce taken.

The effect of nitrogen fertilization on soil physical condition was even more marked in the 3–6-inch layer of Catalina clay as shown in table 1. The application of 800 pounds of nitrogen per acre yearly sharply increased the volume of quickly drained pores (fig. 1) and of pores drained at 60-cm. tension, and the percolation rate with all four grasses. On the average, quickly drained pores were increased by about 30 percent; those drained at 60-cm. tension by about 20 percent; and percolation rates by about 80 percent. This effect of nitrogen fertilization can be attributed to increased root development.

EFFECT OF GRASS SPECIES ON SOIL COMPACTION

Although grass species with heavy fertilization had no marked over-all effect on soil condition in the small plots on Catalina clay (table 1 and fig. 1), the 3–6-inch layer of soil under Pangola grass had more pores drained at 60-cm. tension at both N levels than Napier or Para grasses.

There was apparently no surface-soil compaction under Pangola grass in the large pastures of Catalina clay. No significant difference in bulk density, percolation rates, or volume of large pores occurred between the upper and the 3–6-inch layer of this soil (table 2). The surface 3 inches of Santa Isabel silty clay loam under Pangola grass, however, had less volume of pores drained at 60 cm. of tension than did the 3–6-inch layer, indicating some compaction.

On the other hand, some compaction of the surface soil by trampling occurred under Guinea and Napier grasses in both soils. Volume of pores drained at 60-cm. tension was significantly lower in the upper 3 inches of both soils with these grasses, as were percolation rates in the Catalina clay. The bulk density of the upper 3 inches of both soils under Guinea grass was also significantly increased by trampling.

The fact that better soil physical condition was apparently maintained under Pangola grass than under Guinea or Napier is easily explained. This grass forms a thick, dense sod covering the soil almost completely and trampling effects are distributed over the entire soil surface. Guinea grass,

on the other hand, grows in large clumps with essentially bare soil between, since vegetation cannot thrive here where the soil is thoroughly permeated by the roots and densely shaded by the overhanging leaves of this grass. These bare areas account for about a third of the soil surface. Livestock avoid stepping on the clumps and traffic is concentrated on the bare soil between, accentuating compaction precisely where the soil cores must be taken. A similar condition, although somewhat attenuated, occurs with Napier grass, which also tends to grow in clumps.

Therefore, there may not be much difference in total soil physical condition on a given area under the various grasses, since the untrampled soil under the clumps of Guinea grass would compensate to some extent for the compacted bare areas between.

SUMMARY

The effect of intensive grazing on compaction of Catalina clay and of Santa Isabel silty clay loam as influenced by four grass species and the rate of nitrogen fertilization was determined.

Although both soils were compacted to some extent by grazing animals, the effect was not important and did not extend below the surface 3-inch layer.

Nitrogen fertilization reduced surface-soil compaction in Catalina clay under Pangola, Para, and Napier grasses, but not under Guinea grass, and resulted in increased percolation rates and volume of large pores in the 3–6-inch soil layer with all four grasses.

Surface-soil compaction by livestock was apparently less with Pangola grass than with Guinea or Napier. However, animal traffic is concentrated on the bare soil between clumps of the latter two grasses where the soil cores must be taken, and the untrampled surface under the clumps would have a compensating effect.

Soil compaction by trampling does not appear to be a serious problem with well-fertilized pastures on the typical latosols of Puerto Rico's mountains, even at high stocking rates and with clump grasses.

RESUMEN

Se estudia aquí el efecto del abonamiento con nitrógeno y de la especie de yerba sembrada sobre la condición física de un suelo Catalina arcilloso y Santa Isabel arcilloso lómico bajo pastoreo intenso.

Aunque ambos suelos se pusieron algo más compactos debido al pisoteo del ganado, este efecto no se extendió más allá de las 3 pulgadas superiores.

El abonamiento con nitrógeno disminuyó este efecto del pisoteo en el Catalina arcilloso con las yerbas Pangola, Para, y Napier, pero no con la yerba Guinea. El abonamiento con nitrógeno aumentó la infiltración de agua

en este suelo, así como el volumen de poros de mayor tamaño con estas cuatro yerbas.

Aparentemente, se comprimió menos el suelo bajo la yerba Pangola que bajo de la Guinea o de la Napier. Sin embargo, con estas últimas, el pisoteo se concentró entre las macollas donde por necesidad se tomaron las muestras de suelo, teniendo el area sin pisotear bajo las macollas un efecto compensatorio.

La compactibilidad del suelo por el pisoteo del ganado tal parece no es un problema serio en los pastos bien abonados en suelos latosol típicos de las montañas de Puerto Rico, aún pastando mucho ganado por unidad de terreno y con yerbas de macollas.

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The Application of Fertilizers in Relation to the Handling of Sugarcane Trash

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INTRODUCTION

The proper handling of trash in sugarcane fields is of great importance to Puerto Rican growers because of its direct bearing on the cost of production. Utilization of the trash presents practical difficulties. Many sugarcane planters simply burn it. Samuels *et al.* (*3*)[2] have shown losses in yields of cane and Bonnet *et al.* (*1*) have shown soil losses as a result of the practice of burning the trash.

Aside from burning the cane trash, the methods of handling this material in commercial agronomic practice are either to align it in alternate rows or banks or to leave it untouched in the field. Landrau *et al.* (*2*) have found that the practice of leaving sugarcane trash undisturbed on a lateritic Coto clay soil compares favorably with either aligning the trash or burning it.

Where cane trash is left undisturbed on the field the farmers have wanted to know the best practice for applying fertilizer. Some farmers use the older system of moving the trash away from the base of the cane stool and applying the fertilizer at its base. Other growers, with an eye to economy, favor broadcasting the fertilizer over the cane-trash blanket without manipulating the trash in any manner.

It is the purpose of this paper to report on an experiment designed to determine the best method of fertilizing undisturbed trash. The system of aligning trash as against that of leaving it untouched is also compared.

PROCEDURE

The experiment was planted with sugarcane variety H. 328560 on Vega Alta clay at the Agricultural Experiment Station at Río Piedras. The Vega Alta clay is a highly leached, heavy, slightly plastic clay with a mottled, less permeable subsoil. The experiment was planted on October 13, 1953, and the plant crop harvested 16 months later on January 31, 1955. The trash of the plant crop was subjected to the following treatments:

1. The trash was aligned in alternate banks, a shallow furrow was opened in the center of the clean banks, and fertilizer was applied to the base of each stool.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 91.

2. The trash was aligned in alternate banks, but no shallow furrow was opened, and the fertilizer was applied to the base of each stool.

3. The trash was left untouched except for moving it away from the base of each stool, and then fertilizer was applied to the base of each stool.

4. The trash was left untouched and the fertilizer was broadcast over the surface of the trash.

The size of each plot was 24 feet by 30 feet or about $\frac{1}{60}$ acre. There were six rows 4 feet apart in each plot. Thirty-three-eyed sugarcane seed pieces were used per furrow. The seed pieces were placed in the bottom of the furrow and covered with soil.

The plots were fertilized at the rate of 1,500 pounds per acre of a 15-4-7 formula per crop. The fertilizer was applied as specified under the various treatments no later than 1 month after cutting the ratoon.

Three ratoons were harvested from the experiment. The first was out on January 24, 1956, at 12 months of age; the second on February 25, 1957, at 13 months; and the third on March 2, 1958, at 12 months.

RESULTS

The yields of 96° available sugar and tons of cane per acre are given in tables 1 and 2, respectively. The yields for the plant cane are not presented inasmuch as the treatments were not initiated until the ratoon crops began.

In terms of both sugar and cane tonnage per acre, there were no significant differences between treatments for any of the three ratoon crops. The measured differences between treatments were never higher than 0.40 ton of sugar or 2 tons of cane per acre.

The fact that yields of sugar per acre are not influenced by aligning or leaving the cane trash untouched has a significant economic meaning to the sugarcane grower. With the ever-increasing rates of pay for hand labor, the alignment of cane trash in the field has become almost prohibitive economically. The practice of aligning cane trash can be eliminated from field practices in areas where irrigation is not practiced. Leaving the trash untouched does not affect the yields adversely.

If the sugarcane trash is to be left untouched on the field after cutting the sugarcane, the question arises as to what is the best manner of fertilizing the sugarcane. Most growers have always applied their mixed commercial fertilizer at the base of the cane stool. When the trash is left undisturbed, the growers have usually moved it away from the cane stool, making a little nest. This practice requires much hand labor. A more economical practice is to spread the fertilizer broadcast over the trash either by hand or, at even less expense, using a fertilizer spreader. As seen in tables 1 and 2, both practices of applying the fertilizer are equally good insofar as cane yields are concerned. Therefore, to save money and labor, the application

TABLE 1.—*Sugar yields (tons) of experiment on trash handling as affected by fertilizer applications*

Treatment No.	Treatment	Yield of 96° available sugar per acre for—			
		First ratoon	Second ratoon	Third ratoon	Average of 3 crops
1	Trash aligned in alternate banks with shallow furrows opened in the centers of the cleaned banks	7.87	7.16	7.55	7.53
2	Trash aligned in alternate banks; no furrows in clean bank	8.08	7.54	7.75	7.79
3	Untouched trash plus fertilizer applied at the base of the stool	7.84	7.48	7.45	7.59
4	Untouched trash plus fertilizer applied broadcast on top of the trash	7.90	7.34	7.75	7.66

TABLE 2.—*Cane yields (tons) of experiment on trash handling as affected by fertilizer applications*

Treatment No.	Treatment	Yield of sugarcane per acre for—			
		First ratoon	Second ratoon	Third ratoon	Average of 3 crops
1	Trash aligned in alternate banks with shallow furrows opened in the centers of the clean banks	66	56	58	60
2	Trash aligned in alternate bank; no furrows in clean banks	66	58	58	61
3	Untouched trash plus fertilizer applied at the base of the stool	67	59	59	62
4	Untouched trash plus fertilizer applied broadcast on top of the trash	67	58	60	62

of the fertilizer broadcast over the trash is to be preferred over moving the trash and applying the fertilizer at the base of the cane stool.

The practice of leaving the cane trash untouched is to be used only with sugarcane varieties which are vigorous germinators and ratooners. The trash blanket can smother out a poor germinating cane variety requiring considerable expenditures for replanting.

SUMMARY

Sugarcane variety H. 328560 was grown for four crops on a Vega Alta clay at the Solís Farm of the Agricultural Experiment Station at Río Piedras to test four methods of handling the sugarcane trash. The methods of trash manipulation employed were as follows: 1, Trash aligned in alternate banks with a shallow furrow opened in the center of each clean bank; 2, trash aligned in alternate banks with no furrows opened in the centers of the clean banks; 3, untouched trash plus fertilizer applied at the base of each stool; 4, untouched trash plus fertilizer applied broadcast on top of the trash.

The results with the three ratoons harvested revealed no significant differences in yields of sugarcane tonnage or sucrose per acre among the four treatments used. This indicates that, for cane growing in areas of sufficient rainfall in Puerto Rico, savings in labor costs can be obtained by not aligning the trash. Further savings in costs can be made by applying the fertilizer broadcast by machine over the cane trash.

Leaving the trash untouched in the field is not recommended for cane varieties which are poor germinators or for irrigated cane.

RESUMEN

Con el objeto de probar cuatro métodos para manejar la paja de caña, se llevó a cabo un experimento con la variedad H.328560 en un suelo del tipo Arcilla Vega Alta, en la finca Solís de la Estación Experimental Agrícola en Río Piedras.

Los métodos usados en la manipulación de la paja de caña, fueron como sigue:

1. Paja alineada en bancos alternados con un surco llano abierto en el centro de cada banco limpio.
2. Paja alineada en bancos alternados sin abrir surcos en el centro de los bancos.
3. Paja dejada en el sitio donde se cortó, a la cual se le añadió abono en la base de cada cepa.
4. Paja dejada en el mismo sitio donde se cortó y abonada al voleo.

Los resultados de los tres retoños cosechados no revelaron diferencia sig-

nificativa alguna en su tonelaje de caña o de sacarosa por acre, en los cuatro tratamientos usados.

Esto indica que para caña sembrada en áreas de suficiente lluvia se puede economizar en los costos de producción al no tener que alinear la paja. Esta economía puede resultar si se aplica sobre la paja abono al voleo por medio de máquinas.

No se recomienda dejar la paja en el sitio donde se corte, si en esa área las cañas germinan pobremente o están bajo riego.

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(*Continued from inside front cover*)

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